Tactical Forest Planning
Using the Scheduling and Network Analysis Program
(SNAP II)

by

Thomas E. Mafera

A PAPER

Submitted to

Forest Engineering Department

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Forestry

Completed May 4, 1992

Commencement June 1992

ACKNOWLEDGEMENTS

I would like to express my sincere appreciation to my major professor, John Sessions, for his valuable assistance. I would also like to thank the other members of my committee, Eldon Olsen and Bill Atkinson, for their guidance in the development of this paper.

I am greatly indebted to the following Forest Service employees:

Rick Toupin - Siskiyou National Forest

Dick Brantigan - Daniel Boone National Forest

Steve Phillips - Daniel Boone National Forest

Finally, special thanks go to my wife Debra for all her support and encouragement during the life of this project.

TABLE OF CONTENTS

LIST OF FIGURES

Tactical Forest Planning
Using the Scheduling and Network Analysis Program
(SNAP II)

INTRODUCTION

Approximately 750 million acres, or one-third, of the total area in the United States is in forest land. The United States Forest Service, a 34,000 person agency of the Department of Agriculture, is responsible for the management of roughly 20 percent of the forest land in the United States. The cost to plan, prepare, and administer Forest Service resource management plans approaches $100-200 million annually.

Public land managers emphasize integrated resource management to maintain biological diversity and protect the health of the forest ecosystem. This approach helps to achieve a balance between wildlife, soils, water, timber, visual, and other resource considerations. These multiple resource objectives are addressed in the development of the strategic (long-range) and tactical (short-range) plans used to manage the national forests.

The challenge facing public land managers is to apply the general guidelines of strategic plans to the development of site-specific tactical plans which require a high degree of spatial and temporal resolution. The Scheduling and Network Analysis Program (SNAP II, Sessions and Sessions

1990) was developed to assist forest planners in the development of these detailed tactical plans.

This paper will briefly discuss strategic planning and some of the mathematical models that have been used in their development. Tactical planning will be emphasized. An overview of tactical planning will be followed by a discussion of mathematical models, spatial concerns that are addressed in the tactical plan, and inventory data that are required for plan development. An application of SNAP II will be presented in the form of a case study on a tactical planning area located on the Daniel Boone National Forest in Kentucky.

STRATEGIC PLANNING

National Forest land and resource management planning is required by the Forest and Rangeland Planning Act of 1974, as amended by the National Forest Management Act of 1976 (USDA 1978). These strategic plans are developed to ensure sustainable resource outputs and forest conditions over many decades. The planning horizon is commonly 200 to 300 years, and an estimate of timber, wildlife, and other forest resource outputs is made for each decade. The management requirements of the individual resources are outlined in a set of standards and guidelines that provide direction for plan implementation.

Linear programming is normally used to solve the strategic planning problem. In the formulation of these plans, the forest is divided into smaller analysis areas which are aggregations of land that are similar, in terms of production capability and susceptibility to impacts, but not necessarily contiguous. Management objectives and resource outputs are then identified for each analysis area. The usual objective of the linear programming analysis is to identify a solution that maximizes a resource or monetary output.

Strategic plans tend to be broad in nature because the analysis is conducted using average costs and yields for large land aggregations; a site-specific schedule of harvest areas is not identified. The end result is often a plan that does not guarantee a spatially feasible solution (Nelson et al. 1991). The spatial details required for implementation are left to be resolved in the tactical planning phase.

Mathematical Models

Forest Planning (FORPLAN, Johnson et al. 1986) is the model that is used by the Forest Service in the development of strategic plans. The FORPLAN model builds on other linear programming tools that were developed over the last two decades. The Timber Resource Allocation Method (Timber RAM, Navon 1971) and the Multiple Use-Sustained Yield Calculation Technique (MUSYC, Johnson and Jones 1979) were two predecessors to FORPLAN. These early models were criticized as being primarily timber management tools for scheduling harvests. Although they were capable of handling the temporal aspect of resource management, they lacked the ability to handle the spatial relationships.

The Integrated Resource Planning Model (IRPM, Kirby et al. 1980) was developed to handle the spatial aspects of transportation planning through the use of mixed integer programming. Mixed integer programming allows the analyst to specify variables which cannot take on fractional values in the solution. In resource planning, the transportation system road segments must be either completely built or not constructed at all. The final solution to the problem cannot specify roads to be partially built since this would provide incomplete access to a particular destination. The large number of integer variables used in IRPM limited the number of time periods in the analysis, and spatial resolution limited its application.

One objective of FORPLAN was to build on these earlier models to provide a model that would contain both spatial and temporal resolution in the development of strategic level plans (Iverson and Alston 1986).

FORPLAN was able to address some of the spatial concerns, but its spatial resolution is limited because of the broad scope of this level of planning. This point is supported by FORPLAN's author, K. Norman Johnson (Johnson et al. 1991), who recently wrote:

> *"Forest planning with FORPLAN has been especially deficient in representing spatial requirements in these [forest plan] standards and guidelines such as the dispersion of harvest units across the landscape to meet 'adjacency requirements' and watershed objectives, the spatial distribution of cover and forage for big game, and the shaping and distribution of harvest units to meet scenic object objectives."*

TACTICAL PLANNING

Tactical plans are prepared to implement the management direction and meet the sustained resource outputs identified in the strategic plan. Tactical plan development entails allocating the outputs to smaller planning areas and identifying a specific set of management activities for the next few decades. Consideration of the management requirements of all resources must be incorporated into the formulation of these site-specific plans.

The analysis areas used in strategic planning are divided into logical spatial management units. A specific schedule of harvest units, transportation requirements, wildlife habitat improvement needs, and other resource projects are identified for periods of 10 to 40 years. The details required for on-the-ground implementation are specified for each management unit. Knowledge of the spatial and temporal components of the plan are essential for managers to be responsive to the site-specific issues of natural resource management.

The size of the management units are variable, but may encompass as much as 20,000 acres. It is conceivable for a large management unit to be comprised of as many as 500 to 1,000 stands of timber and 3,000 road segments. The analysis is commonly conducted for a planning horizon that spans one to four decades.

As in strategic planning, the objective is to maximize a physical or monetary output. However, the interrelations of the individual resources, or resource linkages, and their management requirements constrain the problem. Analysis should lead to the adoption of a feasible solution (if one exists) which is responsive to integrated resource management objectives.

Mathematical Models

The development of a tactical plan requires that the outputs identified in the strategic plan be allocated to the individual management units. Disaggregation techniques are being developed for strategic plans (Merzenich 1991). This is an area of active research that will facilitate the application and implementation of strategic plans to site-specific projects.

Important considerations for the forest manager in choosing tactical planning models are: the speed in which the model can arrive at a solution; how well it presents output information; and whether additional alternatives can be evaluated interactively with the model.

Mixed integer linear programming is one method to arrive at an exact solution to the tactical planning problem, but it takes a considerable length of time to arrive at the solution. It may require up to 10,000 integer variables to represent a four period problem with 1,000 units and 3,000 road segments. Covington et al. (1988) report the time to an exact solution for a 300 integer forest planning problem to be eight hours on a minicomputer.

SNAP II is a microcomputer software program designed to assist managers in the development of tactical plans. By keying on the standards and guidelines of forest-level strategic plans that are based on resource linkages, the program is capable of handling the spatial details that strategic planning is not able to address.

In contrast to the mixed integer formulation, the SNAP II heuristic develops many feasible solutions to a problem in minutes. It then ranks the solutions according to economic efficiency.

The objective is to identify the spatial solution that maximizes net present value. SNAP II will meet timber production goals as closely as possible, but priority is given to meeting the specified integrated resource constraints. A five step process is used to develop feasible solutions:

1. Identify the optimal harvest plan in the absence of multiple use constraints by using the parcel, road, harvest, and mill information. This step

evaluates each parcel's intrinsic potential for timber production.

2. Stochastically develop many feasible harvest patterns based on resource constraints and the optimal harvest plan identified in Step 1. As part of this process, the habitat connections are modeled as a Steiner network (Sessions 1992). Recognize the dynamics of forest growth over multiple time periods through seral stage (ecological state of the forest) progression and volume production.
3. Evaluate the harvest and road system network for each pattern that satisfies the spatial constraints using methodology developed by Sessions (1987).
4. Determine the present net worth of each feasible alternative.
5. Prepare tabular and graphical reports for feasible solutions.

Modern tactical planning problems involve thousands or tens of thousands of decision variables. A major challenge is how to report the solution to the analyst so the solution can be quickly understood. The graphics capability of modern hardware and software languages offers the opportunity to provide a variety of graphic reports to convey the solution.

SNAP II provides the analyst with reports that offer a quick means to evaluate a feasible solution. Graphical reports display seral stage distributions through time. Stands proposed for harvest, transport routes, and mill destinations in a specific time period are also spatially shown on graphic screens. The analyst is able to modify solutions to evaluate how changes will affect the economic efficiency of the harvest and the resulting seral stage distributions.

RESOURCE LINKAGES

Tactical planning analysts are often faced with a complex series of spatial constraints that are based on resource linkages. The spatial constraints are quantified at the strategic planning level in the form of implementation standards and guidelines.

The primary resource linkages that are emphasized are: regulating the size of openings; preventing fragmentation of wildlife habitat; and maintaining seral stage distributions for watershed and wildlife management. Other spatial aspects of forest operations include the choice of road locations, transportation routes, and harvest systems.

This high degree of resolution for tactical plans is essential not only to implement the plan on the ground, but to accurately assess the long-term cumulative impacts of the proposed activities.

Opening Size

Timber harvesting entails the removal of all or a portion of the trees on a selected site. The acreage treated during any period of time will affect the state of the forest on that site as well as in adjacent areas. The size of contiguous treatments are controlled to achieve integrated resource objectives. The tactical plan will determine the size and scheduling of harvest treatments.

The management requirements of non-timber resources of the forest ecosystem may dictate that the size of an opening be restricted. For example, it may be desirable to maintain minimum distances from forage to cover for the management of big game. Since good foraging habitat is often associated with the early seral stages found in forest openings, control of opening size will help ensure that the minimum distances are maintained.

Visual quality considerations may lead to another set of opening size restrictions. In addressing visual quality objectives, managers often divide the landscape into zones identified as foreground, middle ground, and background. Each striation across the landscape is associated with a different degree of visual sensitivity. Openings in proximity to the viewer create a greater visual impact and often have more stringent size restrictions than background openings.

Tactical planning analysts handle variations in opening size by defining the seral stage and the attributes associated with a given parcel of land. Attributes describe the physical or spatial characteristics that are associated with a parcel. Each parcel may be assigned several different attributes that describe its characteristics. As the timber grows, stands move through a logical progression of seral stages. Parcels in seral stages classified as openings prevent adjacent stands from being harvested if their combined acreage exceeds the desired opening size. For each attribute, the analyst specifies the seral stages considered openings and the maximum allowable opening size. Different combinations of attributes and seral stages allow the planner to control the opening sizes throughout the management unit. An example of how this applies to visual management follows: The analyst can combine all stands in the foreground into one attribute, specify a maximum allowable cut size of ten acres, and designate the three youngest seral stages as openings. These early seral stages may be associated with the grass/forb, shrub, and sapling states of ecological progression. In contrast, the background stands could be a different attribute group, allow a 40 acre opening, and consider only the two youngest seral stages as openings.

Another important consideration is the relationship between adjacency and opening size. Stand size often varies from 10 to 60 acres within a planning area. Many stands contain fewer acres than the maximum allowable opening size. The tactical plan must recognize this and allow for a combination of more than one parcel to create a larger opening that conforms with the constraint.

Habitat Connections

Resource management often dictates that habitat connections be provided to prevent the fragmentation of critical habitat, provide migration routes, or limit the maximum distance to cover. Habitat connections are defined by a seral stage, or group of seral stages, that satisfy the management criteria of the resource under consideration. Connections are often associated with wildlife habitat management requirements.

Tactical planning analysts may need to identify several connections in a planning area to prevent isolation of wildlife species or provide recreation connections between points of interest. Consideration must be given to the relative suitability of seral stages for inclusion in the connection, whether the connection can vary in location throughout the planning horizon, and the desired width of the connection. For example, big game management may require connections that meet one set of seral stage conditions to connect its critical habitat, while the location of a hiking trail may have a completely different set of seral stage criteria for its connection.

Seral Stage Distribution

Water quality and wildlife habitat management often dictate that the seral stage distribution of a given forest area be controlled to provide a desired set of future forest conditions. This control is achieved by specifying a maximum number of acres that can exist in a given seral stage or group of seral stages at any given moment in time. Habitat requirements of the Northern Spotted Owl in the Pacific Northwest have led to a set of guidelines that demonstrate this point (Thomas et al. 1990). One facet of these guidelines dictates that 50 percent of the land in each quarter-township must be occupied by timber stands that contain trees at least 11 inches in diameter and a minimum of 40% crown closure.

An example of maintaining water quality through the control of seral stage distribution is also found in the Pacific Northwest: For a drainage basin a common upper limit is that 25 percent of the area can be in a given set of seral stages during any time period.

Both of these examples apply to a discrete set of parcels, have an upper bound on the acreage allowed in a set of seral stages, and require that the guideline be met through time.

DATA REQUIREMENTS

The quantity of data that are assimilated for the spatial definition of tactical plans is large (more than a million pieces of data are often needed), so much of the information is currently in Geographical Information Systems (GIS).

Parcel Information

A field inventory of a management unit is conducted prior to the development of the tactical plan. Inventory data are the basic information for analysis. For each parcel, the primary data required are:

* Species composition
* Volume, value, and defect information by species
* Current seral stage
* Alternative silvicultural treatments
* Attributes that describe the stand
* Location

Since the timber in a planning area is not homogeneous, the preparation of the tactical plan requires that a number of different species and/or products be considered. Information on timber quality and amount of defect in a parcel is also important to tactical planning analysts. The dynamic nature of volume growth and yield is also considered. Volume projections for future periods must be made for the range of silvicultural treatments under consideration.

The initial seral stage and silvicultural treatment alternatives are identified for each parcel. Several silvicultural options may be viable for a given parcel. Special consideration must be made to handle the dynamic aspect of forests and project the resulting seral stages for each silvicultural alternative considered in a period.

Allowing units to progress through ecological states is a critical point when one considers how project constraints are based on the control of seral stage distributions. Since tactical plans address the cumulative impacts of proposed actions, the ability to predict forest growth through time is essential in order to ensure the desired future condition of the forest is maintained.

Parcel attributes are the unique set of characteristics that apply to a given stand of timber. Location in terms of visual quality, percent slope, special management zones, and aspect are examples of some of the attributes that may be important to the solution of tactical planning problems. The spatial constraints in tactical planning are addressed using the interrelationships between silvicultural treatment options, attributes, and seral stages.

Location of a parcel is essential to generate harvest patterns that satisfy adjacency requirements. This information, in map or GIS format, is crucial to make the spatial connection between the stands proposed for harvest and the transport routes identified to deliver the products to the mill(s). In GIS format, the X and Y coordinates of parcel boundaries are required. The Z coordinates are optional but are useful for graphical displays depicting the appearance of harvest patterns from various viewing perspectives. This is especially valuable for planning units in visually sensitive areas.

Transportation System Information

Tactical planning also requires information about the transportation system to determine transport, maintenance, and road improvement costs for each road segment. The required data are:

* Node names (intersections, landings, mill locations)
* Road status (existing, proposed, reconstruction)
* Coordinate data (X, Y, Z is optional)
* Attributes that characterize the road segment (length, grade, alignment, and required level of maintenance)

Road attribute information is essential to determine the round trip travel time for a log truck transporting the timber from the harvest area to the mill destination. Road status is important to identify the investment, maintenance, and transport costs involved in delivering the timber to a mill. A travel time matrix that uses road grade and alignment information is one method to identify round trip transport costs (Byrne et al 1960). Average travel speed over the road segments is another method to arrive at this estimate. The location of the transportation system is essential to make the spatial connection between harvest areas and mills.

CASE STUDY - AN APPLICATION OF SNAP II

A management unit from the Daniel Boone National Forest (DBNF) was selected to model in SNAP II. The planning area is referred to as Devil's Creek Resource Analysis Unit and was chosen to demonstrate the complexity of constraints that public land managers face in tactical planning.

Project Area Description

The Devil's Creek area of the DBNF is located on the Cumberland Plateau on the western edge of the Appalachian Mountains (Figure 1). The resource analysis unit contains a diversity of forest types and has several intermittent streams dissecting the area. A series of cliffs run in close proximity to the Cumberland River, the western boundary of the area, and protrude inland around a few of the intermittent stream channels.

Devil's Creek Resource Analysis Unit (Figure 2) totals 1945 acres and is comprised of two sub-areas known as compartments. Compartment 4217 has 1304 acres and Compartment 4220 has 641 acres. Approximately 700 acres of private land are found on six separate tracts within the analysis unit boundary. There are 108 stands of timber and 109 road segments within the planning area (Figure 3).

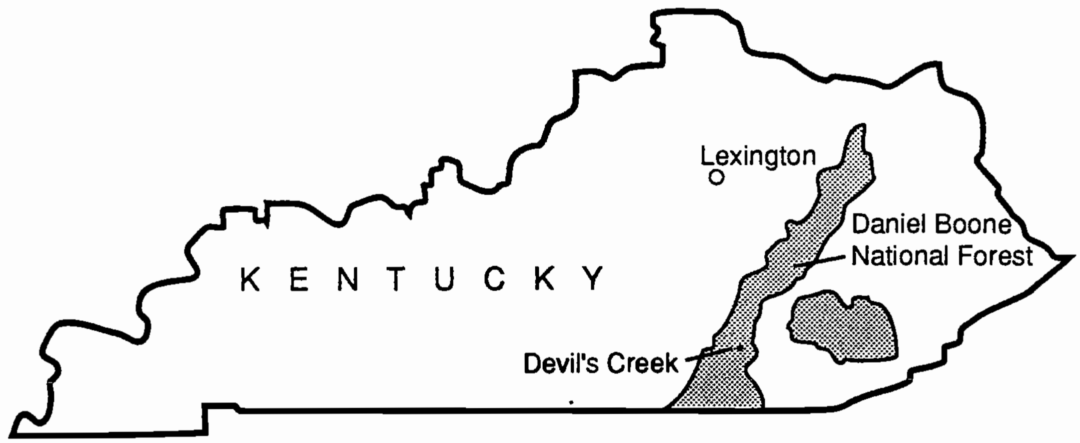

Figure 1. The Devil's Creek Resource Analysis Unit is a tactical planning area located on the Daniel Boone National Forest in Kentucky.

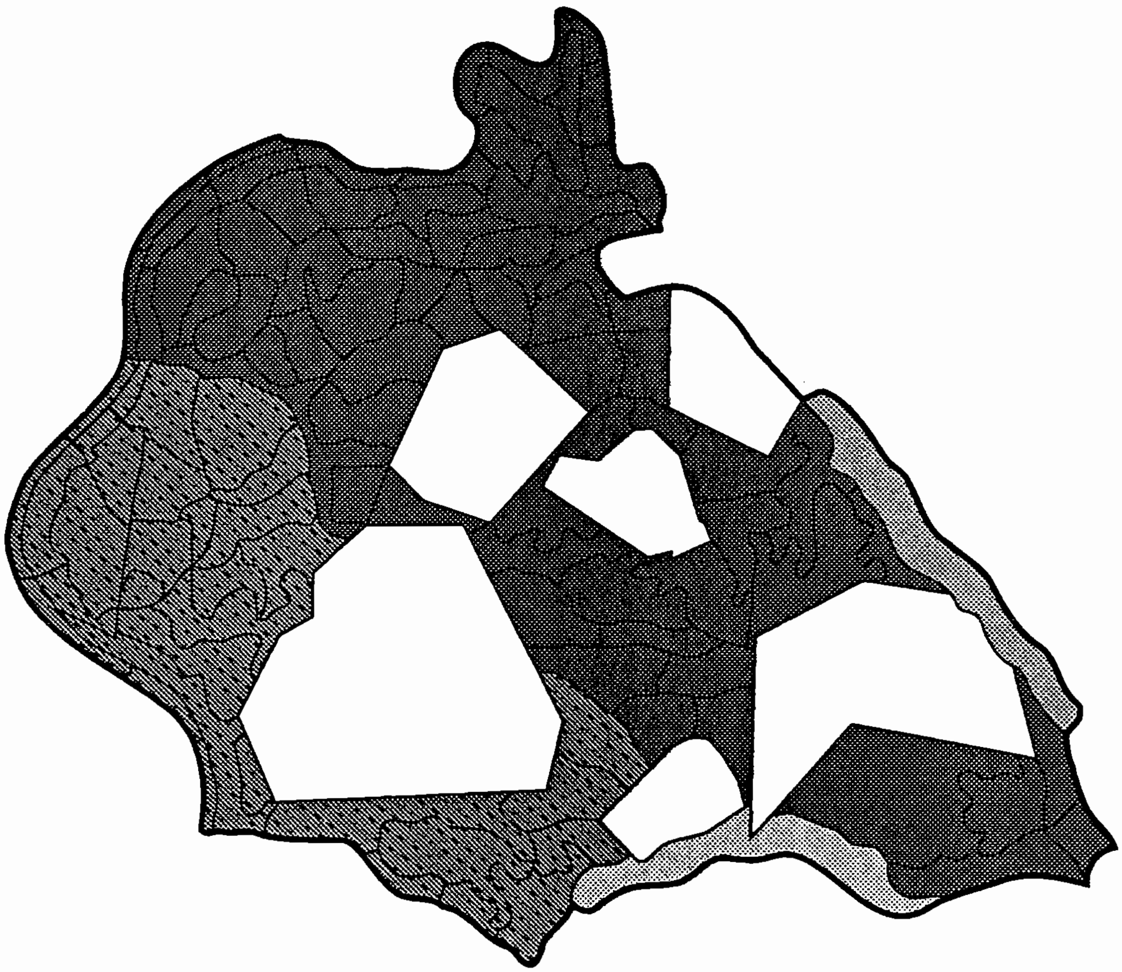

Figure 2. Devil's Creek contains 1,945 acres of national forest land. The area is divided into two compartments (dark gray and dark gray pattern). Approximately 700 acres of private land (unshaded) are within the area boundary. The two elongated parcels (light gray) represent the control polygons used to connect critical habitat for the red-cockaded woodpecker, an endangered species found on the forest.

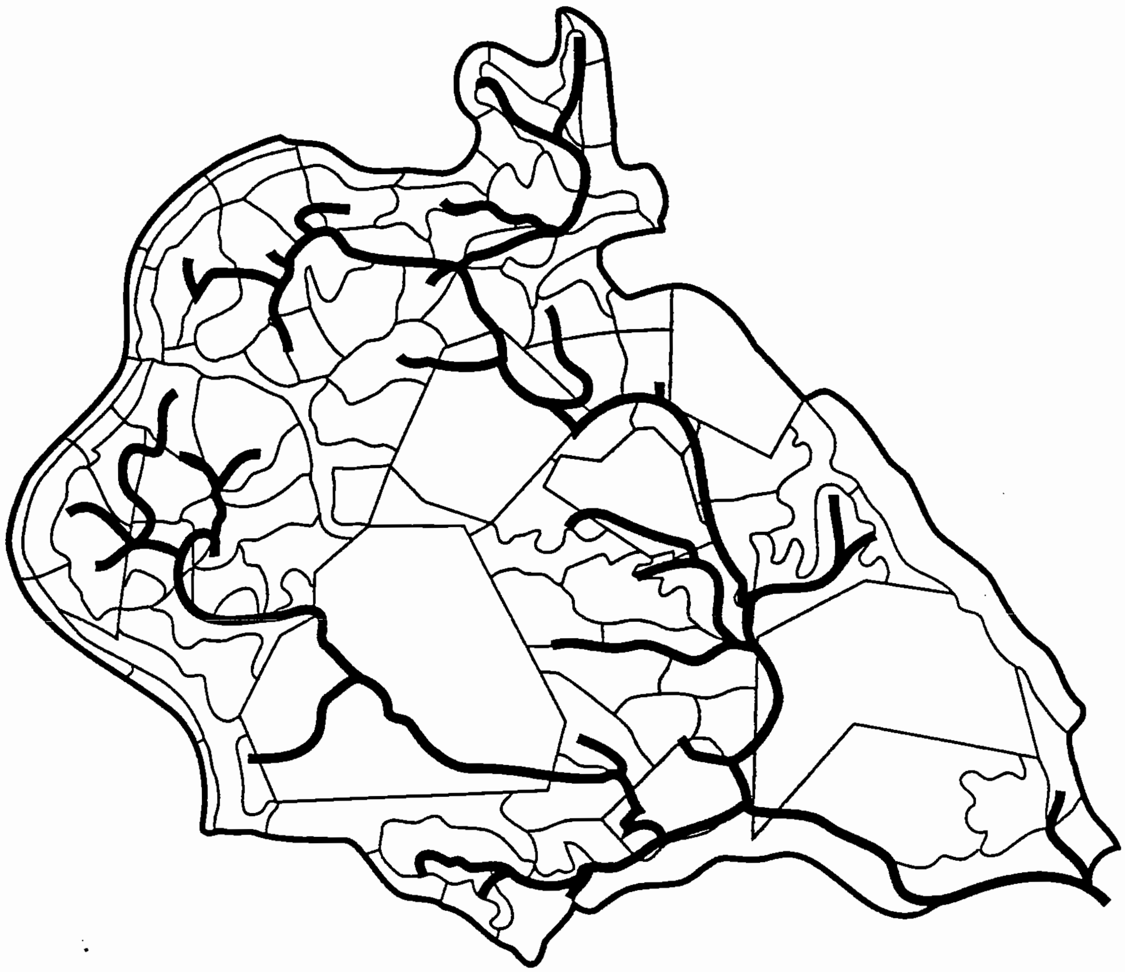

Figure 3. The transportation system required to access the parcels of timber that will be eligible for harvest over the next 20 years.

The forest is managed on an even-aged basis. This means that stands are either planted or regenerated naturally. The stand grows through time and then is treated with one or more intermediate harvests where a portion of the stand is removed. The final regeneration harvest is accomplished by removing the remainder of the stand (clearcut) or by retaining selected trees to provide a seed or shade source to encourage natural regeneration (seedtree or shelterwood).

The DBNF's Forest Land and Resource Management Plan (strategic plan) identifies the level of resource outputs the forest will provide over a decade. The harvest level objective for the decade is broken up into an annual target for each administrative unit (district) on the forest. The tactical planning team, an interdisciplinary team, then allocates the annual target among the resource analysis units to be analyzed in a designated year.

The interdisciplinary team identified an initial harvest, or regeneration, objective of 182 acres for Devil's Creek Resource Analysis Unit. Site-specific inventories provide interdisciplinary teams with more knowledge of the spatial constraints that apply to the planning area and regeneration acreage adjustments are often required. In the case of Devil's Creek, the initial regeneration objective was reduced to 167 acres because of this fact. In order to meet Forest Land and Resource Management Plan output levels, this acreage will need to be made up in other resource analysis units.

The inventory of Devil's Creek resulted in the location of two proposed, endangered, threatened and/or sensitive (PETS) species in the planning area. The special management requirements of these species must be considered in the development of the tactical plan.

Project Constraints

A complex set of constraints such as those that apply to Devil's Creek Resource Analysis Unit make it difficult for managers to identify economically efficient harvest alternatives that adhere to constraints and meet project objectives. A discussion of these constraints are outlined as follows:

Forest Land and Resource Management Plan Constraints:

The DBNF's Forest Land and Resource Management Plan states that the maximum opening size any regeneration area or combination of regeneration areas can be is 40 acres. A stand of timber is classified as an opening until it reaches a height equal to 20% of the height of the surrounding timber. This generally will occur around 20 years of age and has been associated with the first two seral stages (seedling and sapling) of each forest type.

There is a limit of the total acreage that can be in the zero to 20 year age class at any given time. This value is set at 33% of the area suitable for timber management. This constraint is applied to the resource analysis unit and each compartment to ensure that the entire area will maintain the desired seral stage distribution and a dispersal of cutting units. The maximum allowable acreage in these seral stages equates to 612 acres for the resource analysis unit: 413 acres for Compartment 4217, and 199 acres for Compartment 4220.

PETS Constraints - Red-cockaded Woodpecker:

Thirty-five acres have been designated as a recruitment stand for the red-cockaded woodpecker, *Picoides borealis*, a species that is on the federal endangered species list and protected under the laws outlined in the Endangered Species Act of 1973 (USDA 1978). Although this resource analysis unit does not have an active colony, there are two colonies within three miles of the planning area. Since the resource analysis unit contains suitable habitat and there are existing colonies in adjacent areas, a recruitment stand was designated in Compartment 4217. Under the management guidelines that have been developed for the recovery of this endangered species, this recruitment stand must be managed as an existing colony to encourage the species to establish a new colony site.

Foraging habitat must also be provided. Since the woodpecker is dependent on pine habitat for survival, it is desirable to provide this foraging habitat, if available, within one-half mile of the recruitment stand. Foraging requirements call for contiguous pine or pine/hardwood (the pine component is between 50 and 70%) stands to be retained adjacent to the recruitment stand. The red-cockaded woodpecker bores its cavity in live trees and prefers older, weakened stems. As a result, it is desirable to preserve the older pine stands for red-cockaded woodpecker habitat.

These special habitat requirements dictate that the following criteria be met in order to ensure suitable habitat is maintained in the resource analysis unit. Each zone represents the radius from the center of the recruitment stand.

1/4 Mile Zone:

There will be no timber harvested in this zone.

1/2 Mile Zone:

Requirements have been set as a total of 8490 square feet of pine basal (cross-sectional) area, and a total of 6350 stems of pine that are greater that 10" diameter at breast height to be contained within this zone. Stands that are designated to meet this foraging requirement should be greater than 30 years old and will not be harvested. (Figure 4). Formulating this constraint in SNAP II requires the analyst to calculate and determine the stands that will be set aside to meet this requirement.

3/4 Mile Zone:

Maximum opening size is restricted to an average of 25 acres (Figure 5).

Regeneration limits have also been set for the pine and pine/hardwood stands within the 3/4 mile zone. A maximum of 8.5% of the pine and pine/hardwood stands within in this zone can be in the zero to 10 year age class at any point in time. In addition, a maximum of 25% of this suitable habitat can be in the zero to 30 year age class (Figure 5).

The oldest 1/3 of the pine and pine/hardwood acreage within the zone are not allowed to be harvested (Figure 4).

Habitat Connections:

Habitat linkages are designated to connect all colony sites and recruitment stands that lie within three miles of one another. These connections can change over time, but the objective is to provide contiguous stands of pine or pine/hardwood that are greater than 30 years of age. It is

Figure 4. Foraging habitat (dark and light gray) must be provided for the recovery of the red-cockaded woodpecker. Parcels that are part of this critical habitat are not eligible for harvest. The oldest pine timber (light gray) is also preserved for the woodpecker.

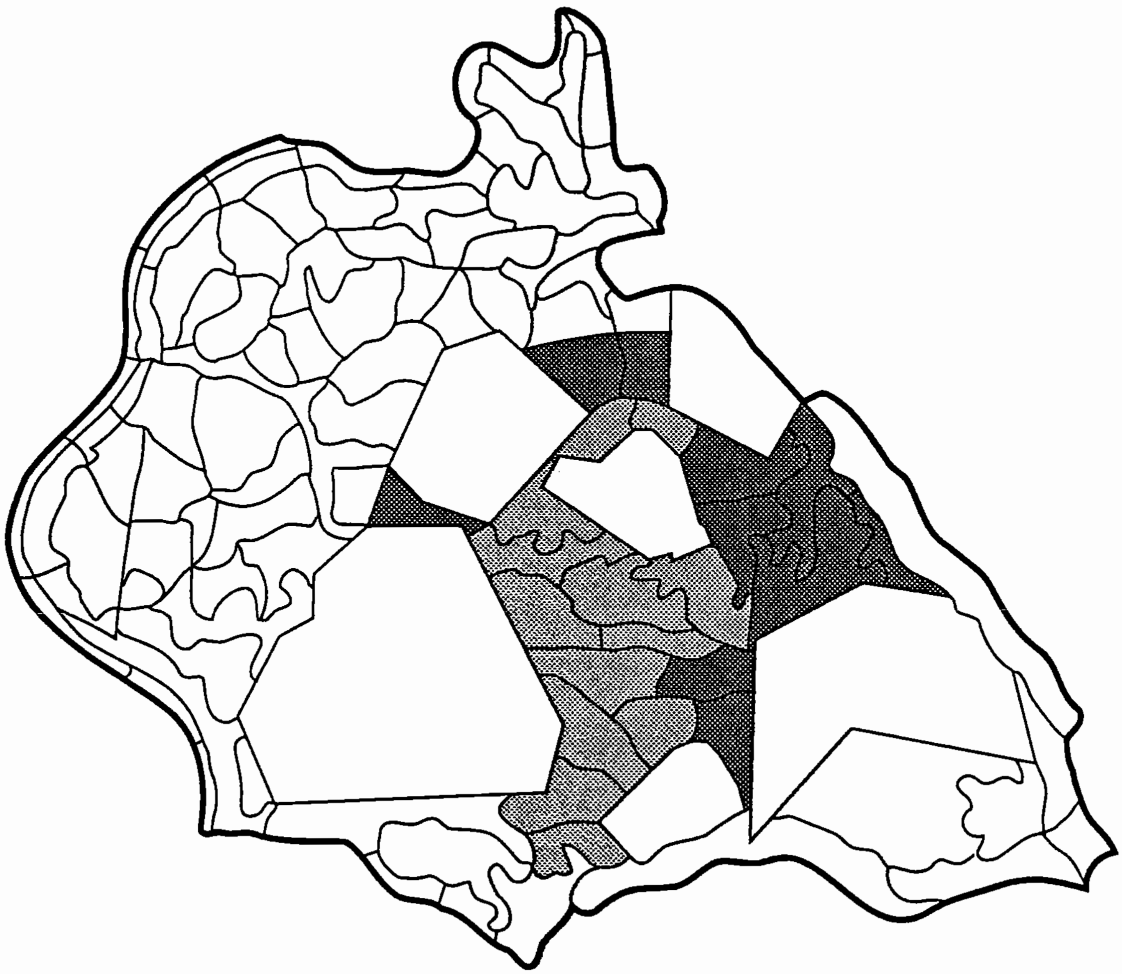

Figure 5. A maximum opening size of 25 acres applies to land within a 3/4 mile radius of the recruitment stand (dark and light gray), a parcel of timber set aside to encourage red-cockaded woodpecker colonization. Seral stage distribution constraints limit timber harvest in parcels that contain more than 50% pine (light gray) to protect the suitable habitat within this 3/4 mile zone.

desirable to keep this connection at least 330 feet wide. "Dummy" stands were drawn adjacent to the resource analysis unit in order to reflect these existing colonies and serve as the control polygons for the habitat connection (Figure 2). The stands are elongated in order to reflect the fact that the connection could have several possible routes to form these linkages.

It is often difficult to find contiguous stands that meet the habitat connection requirement due to the diversity of forest types. This results in a mosaic of stands in forest types that range from pure hardwood to pure pine. It is necessary to examine the forest types that lie between the colony and recruitment stands to identify the best habitat available.

The priority for stands to be included in these connections is dependent on the forest type and age of the timber. The higher the stand's composition of pine and the older the age of the stand leads to a higher priority for the connection. The basal area of pine sawtimber that is found in the stand is a good measure of the suitability of the habitat.

PETS Constraints - Rafinesque Big-eared Bat:

Evidence of the Rafinesque's big-eared Bat, *Plecotus r.*

rafinesquii, has been found in the resource analysis unit. Rafinesque's big-eared Bat is a Category 2 species (currently being reviewed for inclusion on the federal endangered species list). Bat species are found in small caves along the cliffs that dissect the Cumberland Plateau. The timber adjacent to the cliffs serve as the foraging habitat for the bats. Special management requirements of the bat can also be outlined by zone.

1/4 Mile Zone:

No harvest will be allowed within 1/4 mile of the site of a hibernaculum, bachelor colony, or maternity site. A bachelor colony has been located in Compartment 4220 (Figure 6).

1 Mile Zone:

To provide foraging habitat for the species, timber is left intact along the cliffs for a one mile radius from the colony site. The present guidelines call for a 100-foot undisturbed zone along the top of the cliffs and a 200-foot strip to be left below the cliffs.

Silviculture and Timber Constraints:

Silvicultural treatments options identified for the resource analysis unit were primarily shelterwood harvests that retain a timber component in order to meet the

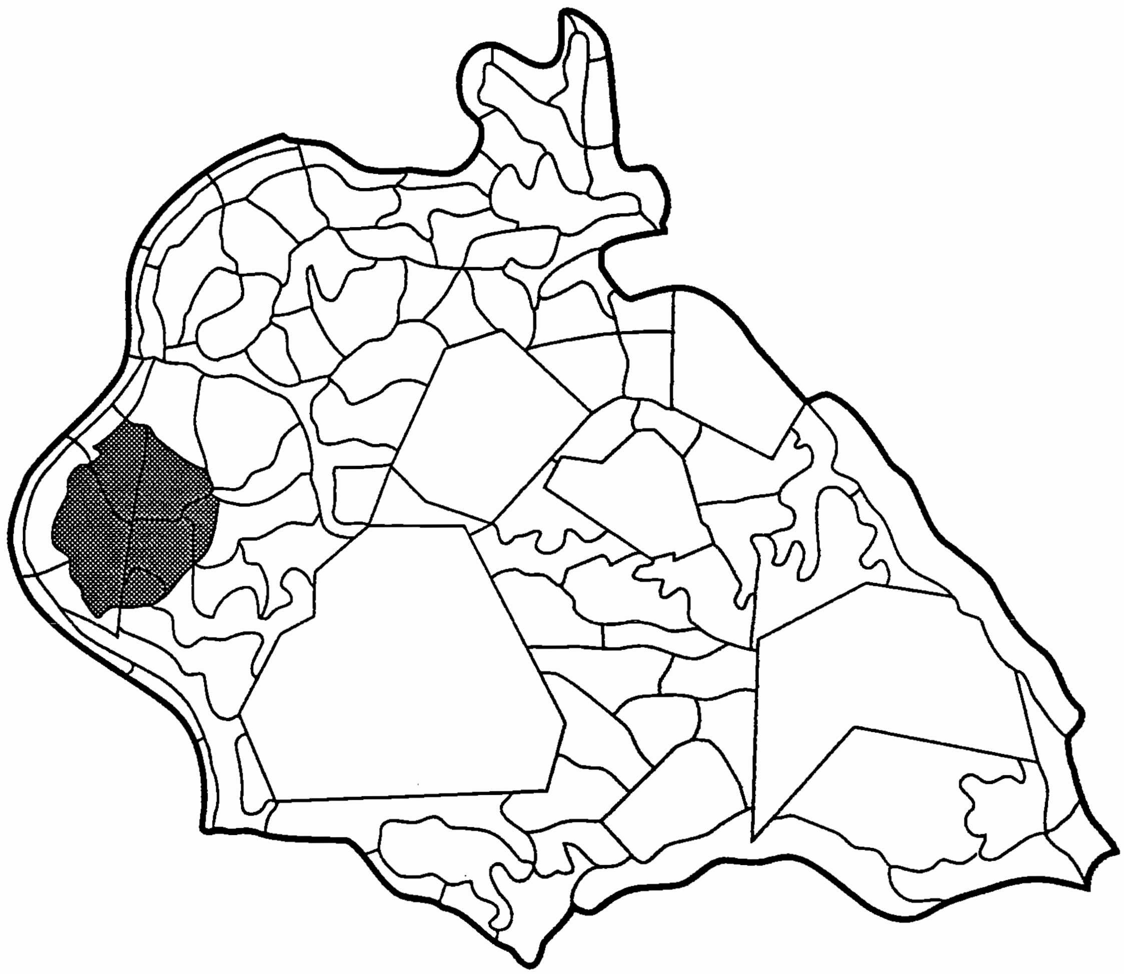

Figure 6. Timber harvest is prohibited within 1/4 mile of a Rafinesque big-eared bat colony site. The bat is under review for inclusion on the federal endangered species list.

management requirements of other resources. Visual shelterwoods are required along the Cumberland River in order to maintain visual quality and "Red-cockaded Woodpecker Modified Shelterwoods" enhance critical habitat in the red-cockaded woodpecker 3/4 mile zone by retaining the pine component.

The solution to this problem is driven by the regeneration objective of 167 acres. The interdisciplinary team identified this adjusted objective in order to ensure that a biologically and economically feasible solution could be identified for the resource analysis unit.

Results and Discussion

In order to demonstrate the advantages of developing tactical plans using the SNAP II model, analyses were conducted using conventional planning techniques and SNAP II. The alternative generated for Devil's Creek using the interdisciplinary team process was "hard wired" (coded) into SNAP II to compare the two alternatives on the same basis.

Present analysis techniques require team members to manually develop spatially feasible alternatives through the compilation of hand calculated data or output generated through the use of various computer software tools. Software programs are available to help identify seral stage distributions, wildlife habitat capability, and present net worth of alternatives. Interpretation of these outputs is made by the resource experts on the team to develop an alternative that considers all resource objectives.

This type of analysis can be time consuming, especially if several alternatives are examined. The number of alternatives that can be evaluated in detail is often limited because of project completion deadlines. There is no guarantee that the alternative selected is the most economical solution to the problem because other economical alternatives that are responsive to the constraints may not have been identified in the analysis.

To illustrate this point, an alternative was developed by the interdisciplinary team using conventional planning techniques. This plan proposed a harvest of 167 acres in the first ten year period and 98 acres in the second period. This spatially feasible alternative was hard-wired into SNAP II to evaluate the economic efficiency of the proposal.

A second analysis was modeled in SNAP II using the same regeneration objectives. The project constraints, parcel data, and transportation system information were used in the Devil's Creek SNAP II formulation.

In the first step of the analysis, the model identifies each parcel's intrinsic potential for timber production and identifies an optimal harvest plan. The relative unit values for the stands in Devil's Creek are presented in Figure 7. Examination of this graphic display shows that stands adjacent to the Cumberland River (the western boundary of the area) have low relative unit values. These stands are associated with high harvest costs, low volume, and high transportation costs because they are located at the terminus of the transportation system.

The SNAP II heuristic then incorporates the resource constraints into the problem in order to identify feasible alternatives. The red-cockaded woodpecker habitat connection requirement is solved in this phase (Figure 8).

The best solution the program identified for Devil's Creek resulted in an improvement in the economic value over the conventional planning technique by $15,970. The SNAP II model identified several harvest patterns that provided more economical solutions than the alternative developed by the team. The units identified for harvest and the associated transportation system used to deliver the products to the mill are presented in graphical reports (Figure 9).

Naturally, the interdisciplinary team must still evaluate the SNAP II solution to determine how well it meets the resource objectives that may not be so easily quantified in a mathematical model. However, SNAP II provides additional reports for each period that can help the team to assess how well solutions respond to cumulative impact

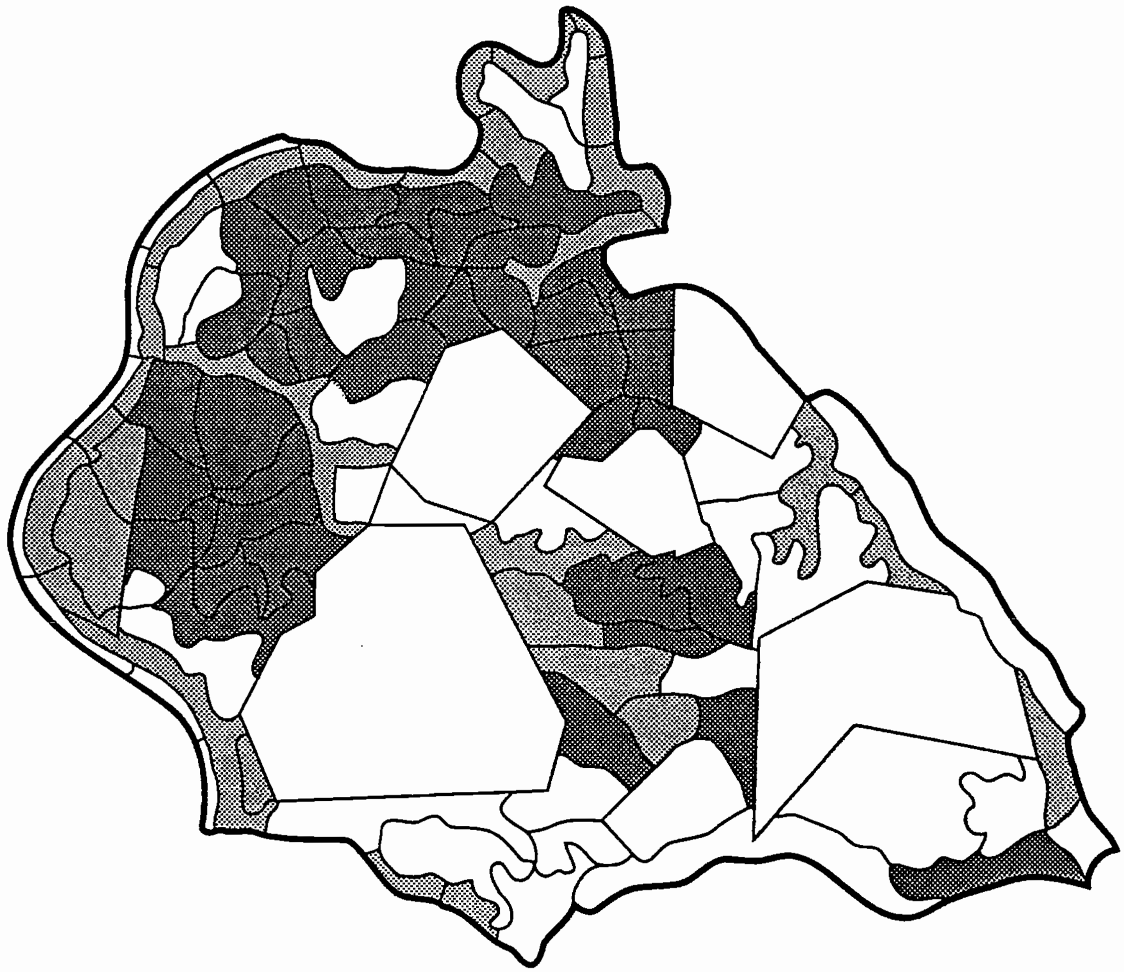

Figure 7. SNAP II identifies the relative timber value of each stand in the planning area based on parcel and transportation system information. Stands are grouped in positive (dark gray) and negative (light gray) categories. Unshaded areas are private land, stands too young for harvest, water, or "dummy" stands for the red-cockaded woodpecker habitat connections.

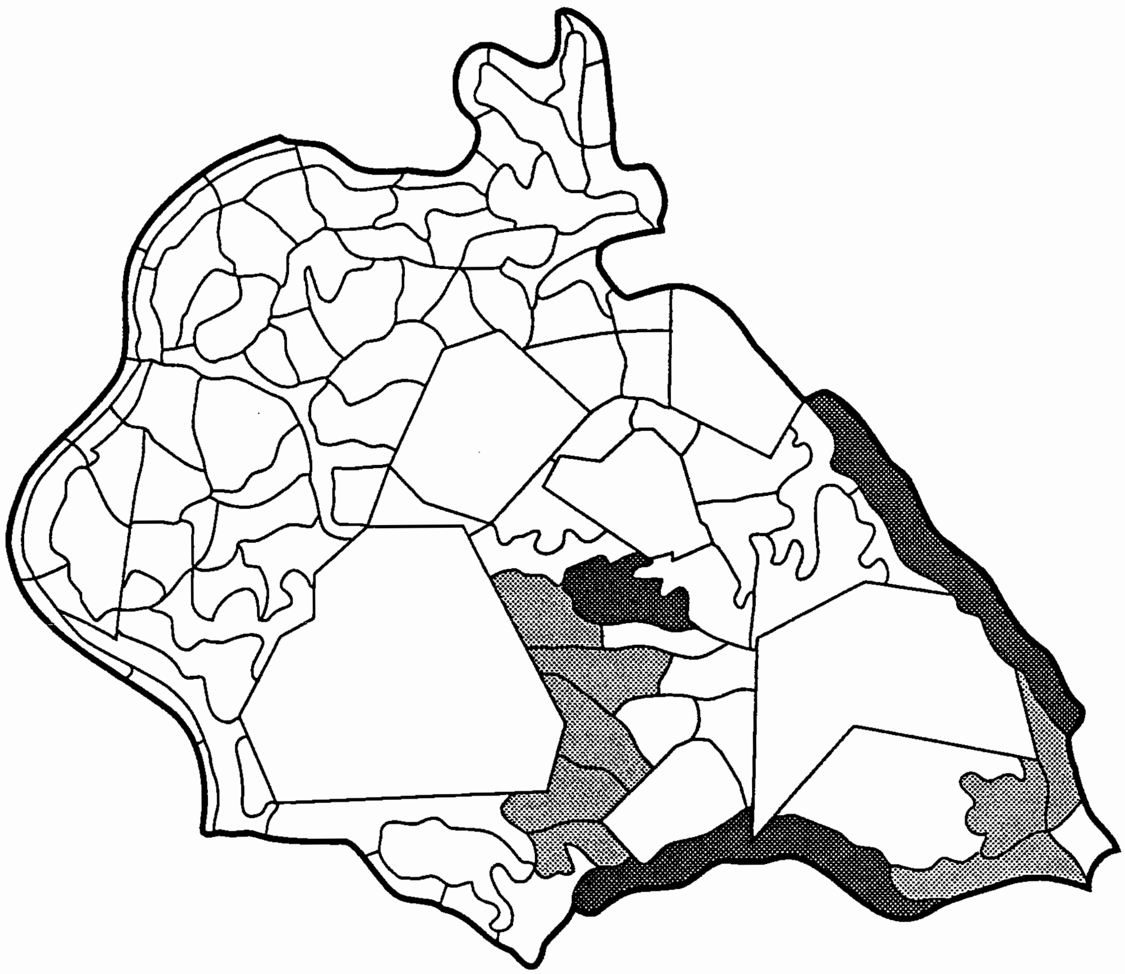

Figure 8. The SNAP II habitat connection solution for the first period. Dark gray parcels represent the control polygons (existing colonies and the recruitment stand) that must be connected with suitable foraging habitat. The stands included in this connection (light gray) are based on a priority established by the analyst.

Figure 9. The SNAP II solution for the two period analysis. Harvest areas for Period 1 (light gray) and Period 2 (dark gray) are shown along with the roads required to transport the timber to the mill.

issues.

Graphical reports on seral stage distribution, big game habitat effectiveness, habitat connections, harvest and transportation patterns, and silvicultural treatment by period are available. These reports provide the analyst with a picture of how the characteristics of the planning area will appear over time. Tabular reports summarize the operational details of volume harvested, harvest and transport costs, transportation path to mill, and complete cost and acreage summaries by designated periods.

SUMMARY

The resource experts that comprise the interdisciplinary planning teams can use SNAP II to their advantage in the development of alternative management actions that contain the spatial and temporal resolution required in tactical plans. Without tools such as SNAP II, teams may not be able to identify a feasible alternative or may develop an alternative that meets resource objectives but may not consider a comparable plan that would lead to greater economic efficiency.

A primary advantage of SNAP II is that the analyst can modify the problem and evaluate additional alternatives. This interactive process allows an interdisciplinary team to evaluate a wide range of options in a relatively short period of time. This is important in order to assess trade offs between resource objectives, economic efficiency, and how well a solution approximates a desired future state for the forest.

The graphical and tabular reports generated by SNAP II for each period provides forest planners with means to assess the long-term cumulative effects of each proposed alternative. The team is provided with information to examine many feasible alternatives in order to select the one that is most responsive to the project's integrated resource objectives.

As the Forest Service prepares to start another 10-year planning cycle, the role of SNAP II has become increasingly more important. SNAP II projects are being prepared on National Forests in Alaska, California, Oregon, and Washington. Additional SNAP II analyses have been conducted by the Washington Department of Natural Resources and the Warm Springs Indian Reservation in Oregon.

SNAP II is designed for 32-bit, 386-compatible microcomputers with INTEL math coprocessors running using DOS. An EGA or better graphics adaptor, color monitor, and mouse are required. Hard disks should have at least four megabytes of available space to store the computer codes and reports. Performance can be enhanced by using a memory cache and/or a large RAM disk.

SNAP II is public domain software. Questions about its availability and documentation should be directed to: U.S. Forest Service, Division of Timber Management, Attention: Don Nearhood, Box 3623, Portland, OR 97208.

BIBLIOGRAPHY

Covington, W.W., Wood, D.B., Young, D.L., Dykstra, D.P., and Garrett, L.D. 1988. TEAMS: A Decision Support System for Multi-Resource Management. Journal of Forestry 86 (8): 25-33.

Byrne, J.J., Nelson, R.J., and Googins, P.H. 1960. Logging Road Handbook: The Effect of Road Design on Hauling Costs. U.S. Department of Agriculture. Handbook 183. U.S. Government Printing Office. 65 p.

Iverson, D.C. and Alston, R.M. 1986. The Genesis of FORPLAN: A Historical and Analytical Review of Forest Service Planning Models. General Technical Report INT-214. Ogden, UT: USDA Forest Service, Intermountain Research Station. 31 p.

Johnson, K.N., Franklin, J.F., Thomas, J.W., and Gordon, J. 1991. Alternatives for Management of Late Successional Forests of the Pacific Northwest. A Report to the Agriculture Committee and the Merchant Marine and Fisheries Committee of the U.S. House of Representatives, Washington, DC.

Merzenich, J. 1991. Disaggregation of Strategic Plan Harvests to Watershed Subunits. In Proc: "Pacific Rim Forestry-Bridging the World", Society of American Foresters, Aug. 4-7, 1991. San Francisco.

Nelson, J., Brodie, J.D., and Sessions, J. 1991. Integrating Short-Term, Area-Based Logging Plans with Long-Term Harvest Schedules. Forest Science 37 (1): 101-122.

Sessions, J. 1987. A Heuristic Algorithm for the Solution of the Variable and Fixed Cost Transportation Problem. In: Proceedings of the 1985 Symposium on System Analysis in Forest Resources. Center for Continuing Education, University of Georgia, Athens.

Sessions, J. and Sessions, J.B. 1991. Scheduling and Network Analysis Program (SNAP II) Users Guide. 139 p.

Sessions, J. and Sessions, J.B. 1992. Post-New Forestry Tools for Tactical Forest Planning. Western Wildlands 17 (4): 39-44.

Sessions, J. 1992. Solving for Habitat Connections as a Steiner Network Problem. Forest Science 38 (1): 203-207.

Thomas, J.W., Forsman, E.D., Lint, J.B., Meslow, E.C., Noon, B.R., and Verner, J. 1990. A Conservation Strategy for the Northern Spotted Owl: Report of the Interagency Scientific Committee to Address the Conservation of the Northern Spotted Owl. Portland, OR. U.S. Government Printing Office. Document # 1990-791-171/20026. 427.

USDA Forest Service. 1978. The Principal Laws Relating to Forest Service Activities. U.S. Department of Agriculture. Handbook 453. U.S. Government Printing Office. Document # 1978 726-724/421 1-3. 66-68; 275-289; 343-359.

USDA Forest Service. 1985. Draft environmental impact statement for the land and resource management plan for the Daniel Boone National Forest. Winchester, KY.

USDA Forest Service. Daniel Boone National Forest. 1990. Cliffline Management Policy. Winchester, KY. 5 p.

USDA Forest Service. Region 8. 1990. Implementation Guide for Red-cockaded Woodpecker Interim Guidelines. Atlanta, GA. 30 p.